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Assessment of Usability in Health Referral Queue Systems: A Business Process Model and Nielsen's Heuristics Analysis

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Abstract: This paper presents a comprehensive assessment of the usability in Health Referral Queue Systems through the lens of a public health management problem. To tackle the challenges encountered in Ibia, Minas Gerais, Brazil, a pioneering solution named the "Fila de Encaminhamento de Especialidades Médicas de Ibiá" (FEEMI) was devised, translating to the "Referral Queue for Medical Specialties in Ibiá" in English. The study involved the modeling of the existing manual health management process using Business Process Model and Notation (BPMN). A comparative analysis between the manual and automated processes revealed a significant reduction in manual tasks, from all 16 to merely 5, including crucial aspects such as medical exams and patient treatment. The FEEMI system successfully automated 10 tasks, streamlining health processes and enhancing overall efficiency. The system underwent rigorous testing, including unit tests and usability assessments based on Nielsen's Heuristics. The results indicated the robust functionality of the FEEMI system, ensuring error-free execution of critical functionalities and showcasing its resilience in handling potential issues. For patients, the FEEMI system introduces a new paradigm, offering improved quality of life and heightened security in health management processes.

Keywords: usability assessment, Health Referral Queue Systems, FEEMI system, public health management, BPMN modeling, Nielsen's Heuristics analysis, software engineering

1. Introduction

Access to quality healthcare is a fundamental human right, yet it remains an elusive privilege for many people in emerging countries [1–3]. The glaring disparities in healthcare services between developed and emerging nations raise deep concerns about the well-being and future prospects of millions of individuals and communities [4–6]. The pressing issue of universal healthcare assistance in emerging countries has attracted the attention of policy makers, healthcare professionals, and global organizations alike, all recognizing the urgent need to bridge the gap and ensure that essential healthcare services are accessible to all [3, 7, 8].

The importance of universal healthcare assistance in emerging countries cannot be overstated. Emerging nations, characterized by rapid economic growth and transitioning societies, face unique challenges in providing adequate healthcare to their populations [7, 9, 10]. These challenges include limited financial resources, infrastructure constraints, and evolving healthcare needs that require innovative solutions. It is within this complex landscape that the concept of universal healthcare assistance becomes crucial [10–12].

Modeling a process is instrumental in uncovering inefficiencies and failures within the workflow, providing a visual representation that allows for meticulous analysis [13, 14]. This step serves as a diagnostic tool, offering insights into bottlenecks and areas for improvement, ultimately enhancing the overall efficiency of the process. Automating a modeled process through Information Technology (IT) systems is pivotal for ensuring enhanced security, traceability, agility, and manageability [13–16]. By leveraging technology, organizations can implement systematic controls, reduce manual errors, achieve rapid execution, and establish a robust framework that fosters secure[1] and transparent operations [17, 18].

We know that it is important to explore and highlight the importance of establishing universal healthcare programs in emerging countries. By examining the multifaceted dimensions of this issue, and based on the development of the system proposed here, we will delve deeper into the impact of accessible health services at the economic, social, and individual levels, especially

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[1]World Health Organization [19]. Operational framework for primary health care: transforming vision into action.

in municipalities in the interior of emerging countries [2], where access to information is scarcer. We will also analyze the role of the system in contributing to the definition and implementation of IT systems that can help and support health policies that meet the diverse needs of its populations [14, 18].

As we move through the discussion that follows, it is important to keep in mind that universal health care assistance is not just about providing medical care; it is about addressing systemic inequalities, promoting social inclusion, and ensuring that everyone, regardless of their socio-economic status, can lead a healthier and more fulfilling life. In this work, we will explore systematization and access to information through a case study. By exploring this vital topic, we hope to shed light on the imperative nature of universal health care assistance. With our system, from the reports produced, we hope to offer insights into how emerging countries can overcome the challenges they face to build a healthier and more equitable future for their citizens.

The main objective of this paper is to analyze the significance and implications of the decision made by the municipality of Ibiá, Minas Gerais, Brazil to grant public access to the medical specialty queue, following the City Council Chamber's deliberation. We aim to model it using Business Process Model and Notation (BPMN) to identify process gaps, bottlenecks, and explore avenues for efficient management. Furthermore, after modeling it using BPMN, we plan to propose an automation system called the "Referral Queue for Medical Specialties in Ibiá". In Portuguese, it is referred to as "Fila de Encaminhamento de Especialidades Médicas de Ibiá" (FEEMI). This software was registered[2] with the National Institute of Industrial Property (INPI) in Brazil. This decision marks a crucial step toward enhancing transparency and accessibility in the provision of healthcare services in the region. Our study focuses on understanding public business processes in Brazilian public health to develop a novel solution for managing queue administration.

2. Theoretical Foundation

In this section, we will delve into essential concepts surrounding BPMN, Nielsen's Heuristics [20, 21], and explore pertinent related works on BPMN process modeling and automation using information systems [22] in the context of public health in Brazil. BPMN serves as a powerful framework for visually representing and analyzing business processes, providing a standardized notation for improved communication and comprehension [13, 14, 16]. Nielsen's Heuristics, on the other hand, offer a set of principles to evaluate the usability of user interfaces, guiding the design of effective and user-friendly systems [21].

To ground our proposed healthcare queue management system, we will delve into relevant literature examining BPMN and information system automation applications within the Brazilian public health context. This exploration will solidify our understanding of the theoretical underpinnings and practical benefits that inform our system's design.

2.1. Business process model and notation

Business Process Management (BPM) is a holistic approach to managing and improving business processes within an organization [15, 23]. It involves the systematic design, execution, monitoring, and optimization of business processes to achieve organizational goals. BPM encompasses methodologies, tools, and techniques aimed at enhancing efficiency, effectiveness, and adaptability in business processes. It is a broader management discipline that focuses on aligning business processes with strategic goals, improving performance, and fostering continuous improvement.

BPMN is a graphical representation standard used for modeling business processes. It provides a visual notation that is easy to understand by both technical and non-technical stakeholders involved in a business process [13, 15]. BPMN diagrams use standardized symbols to represent various elements and activities within a process, making it a powerful tool for designing, analyzing, and improving business processes [15, 16]. In this context, it is important to emphasize that BPMN allows for the clear visualization of the steps involved in managing a patient queue. This clarity helps stakeholders, including healthcare providers and administrators, understand the workflow and identify areas for improvement [13, 16].

Besides that, modeling a queue with BPMN enables the identification of bottlenecks and inefficient processes in the patient journey. This insight is crucial for optimizing the workflow, reducing waiting times, and improving overall efficiency in healthcare service delivery. In Brazil, the public health system is a complex process, and it is crucial to highlight that BPMN serves as a universal language for facilitating communication among diverse stakeholders [13, 23]. By modeling the queue management process, it becomes easier for IT professionals, healthcare providers, and administrators to collaborate, share insights, and work toward a more effective system.

The modeling process allows for the identification of potential risks and challenges in the queue management system. This proactive approach enables healthcare organizations to implement strategies to mitigate risks, ensuring a smoother patient experience and it becomes apparent where resources are allocated within the queue management process [13, 14]. This insight helps healthcare administrators make informed decisions about resource distribution, ensuring that the right personnel and facilities are available to manage patient queues effectively. BPMN supports a continuous improvement mindset [13, 16]. By modeling the queue management process, healthcare organizations can regularly review and refine their processes based on data-driven insights and feedback, leading to an ongoing enhancement of patient services.

Healthcare processes often need to adhere to regulatory standards. BPMN provides a standardized way to represent processes, making it easier for healthcare organizations to ensure compliance with industry regulations and standards. A BPMN model of the queue management process allows for easier adaptation to changing conditions, such as shifts in patient volume or the introduction of new healthcare services [13, 14]. It facilitates agility in response to evolving healthcare needs.

Finally, BPM is a broader discipline that encompasses the strategic management of business processes, while BPMN is a specific notation language used to model and visually represent those processes. BPMN is often utilized as a tool within the larger framework of BPM to create standardized and easily understandable visual representations of business processes. BPMN serves as a valuable tool for modeling and improving the patient queue management process. By providing a clear, standardized representation of the workflow, BPMN enables healthcare organizations to optimize processes, enhance communication, mitigate risks, and continuously improve the delivery of healthcare services to patients.

[2]Certificate of Registration for the FEEMI Computer Program, BR512023003055-4, issued by the National Institute of Industrial Property on October 17, 2023.

2.2. Nielsen's heuristics

Nielsen's Usability Heuristics are a set of 10 general principles or guidelines developed by Nielsen [21], a renowned usability expert, to evaluate and improve the usability of user interfaces. These heuristics serve as a framework for assessing the effectiveness, efficiency, and satisfaction of interactive systems, websites, and software applications. Nielsen's 10 Usability Heuristics can be applied to evaluate your queue management system in municipality of Ibiá of Minas Gerais (MG) in Brazil [24]. These heuristics provide essential guidelines for assessing and improving the usability of your system. Here are Nielsen's 10 Usability Heuristics:

1) Visibility of System Status: Ensure that the system keeps users informed about their actions and the system's response. In the queue system, provide clear feedback on the user's position in the queue, estimated waiting times, and updates on service availability.
2) Match Between System and Real World: Use terminology and concepts that are familiar to the system's users. Ensure that the system's interface and labels reflect the language and mental models of healthcare service seekers in Ibiá.
3) User Control and Freedom: Users should have the ability to navigate the system with ease and the freedom to correct their actions. For instance, allow users to update or cancel their position in the queue if they change their plans.
4) Consistency and Standards: Maintain a consistent interface design throughout the system. Ensure that buttons, icons, and navigation elements follow established design standards for better user predictability.
5) Error Prevention: Design the system to minimize user errors, especially when they register or update their information. Include validation checks to prevent common errors.
6) Recognition Rather Than Recall: Provide a user-friendly system that does not demand extensive memory load. Show patients their relevant information and options clearly without requiring them to remember details from one interaction to the next.
7) Flexibility and Efficiency of Use: Consider the needs of novice and experienced users. Implement shortcuts and efficient paths for common tasks to cater to various user levels.
8) Aesthetic and Minimalist Design: Keep the interface clean and uncluttered. Prioritize essential information, making it easy for users to focus on their queue status and relevant details.
9) Help Users Recognize, Diagnose, and Recover from Errors: If users encounter errors or have difficulty, provide clear and concise error messages with guidance on how to rectify the situation.
10) Help and Documentation: Offer easily accessible help resources for users, such as a guide on how to use the system, frequently asked questions (FAQs), and support channels for assistance with any issues or queries.

By applying these usability heuristics to your queue management system, you can identify areas for improvement, enhance the user experience, and ensure that healthcare service seekers in Ibiá have a more accessible and efficient system for managing their medical specialty referrals.

2.3. Related works

Efficient queue management is a fundamental concern in the healthcare context. Bernardes Senna et al. [25] have proposed software called the Hospital Admission and Surgery Authorization Request System, in Portuguese language it is called Sistema de Solicitação de Autorização de Internação Hospitalar e Cirurgia (SISAC), to address this concern. SISAC was designed to organize the queue based on clinical and chronological parameters, allowing for transparent and effective consultation of the list. This is of great importance, as queue management is crucial in reducing complications resulting from delays in surgical procedures.

The use of information technology in the healthcare sector is a growing trend. The SISAC software developed by Bernardes Senna et al. [25] is an example of this technological advancement that modernizes and streamlines the work of medical professionals involved in the care of surgical patients. This technology provides a more precise and efficient approach and allows for prioritization based on clinical guidelines. Electronic access to procedure tables and disease codes reduces the likelihood of completion errors and improves record accuracy.

The validation of the software is an essential component of the successful implementation of information systems in healthcare. The study by Bernardes Senna et al. [25] emphasizes the importance of validating computerized systems in the context of quality assurance, complying with good manufacturing practices. However, it is important to note that while the software has shown great potential to improve the management of elective surgery waiting lists, the research was based on simulations and not on direct application with the target audience. It is worth noting that the Specialty Medical Referral Queue System in Ibiá, Minas Gerais, Brazil arises from a real need, as reported by the system's author, who needed to track his position in the nephrology specialty queue in practice, with no possible means of doing so. Therefore, driven by both practical necessity and public demand, as well as the request of the city's council, the system was implemented.

The article *Validity Evidence for an Elective Surgical Queue Management Software* underscores the paramount importance of effective queue management in the healthcare sector [25]. Emphasizing the necessity for innovative strategies to optimize surgical queue processes and elevate the overall patient experience, the research advocates for solutions that bring transparency and efficiency to healthcare service management. The specialty queue software implemented in Ibiá addresses these concerns by enabling patients to monitor their position in the queue. This aligns with the findings of dos Santos et al. [26], who stress the significance of meticulous surgical scheduling for resource optimization and enhanced perioperative care.

The study conducted by de Azevedo Guimarães et al. [27] focused on evaluating the usability components of the Brazilian immunization information system (IIS), specifically examining user interaction and agility with the interfaces. Using a concomitant and convergent mixed-method approach, the research employed a cross-sectional design for quantitative analysis and the indirect method of heuristic evaluation for the qualitative aspect. The study involved 137 nursing professionals working in vaccination rooms who completed a structured questionnaire on usability quality standards. Additionally, four information technology specialists utilized a semi-structured form to conduct a software inspection. The evaluation revealed 10 violated heuristics and identified 14 usability problems across the 68 screens of the IIS. The system exhibited primarily simple usability problems (grade 2 severity) with a low correction priority. Notably, error prevention (3.03 ± 0.54) and help and documentation (3.00 ± 0.68) were the heuristics best evaluated, while visibility of system status received the lowest evaluation with a mean of 2.62 ± 0.55. Furthermore, professionals with a technical education level demonstrated a higher score on the recognition rather than recall heuristic compared to nurses (2.77 ± 0.49 vs. 3.67 ± 0.66, $p = 0.003$). While the system offers easy access for users, it exhibits weaknesses in facilitating users to easily achieve their interaction goals with the interface.

In Banta and Almeida's study [28], authors offer a comprehensive overview of health technology assessment (HTA) in Brazil. Conducting a descriptive analysis, the authors draw insights from their experiences and relevant literature. HTA interest emerged in Brazil in the mid-1980s, marked by seminars and consultations with international participants. According to Banta and Almeida [28], over time, Brazil developed expertise in HTA, and in 2003, federal policies were introduced to integrate HTA findings into clinical, management, and policy decisions. The last 5 years witnessed rapid institutional development across government, private entities (especially prepaid health plans), academia, and research institutes. Policy adjustments are crucial for optimizing impact, and further institutional development can catalyze this transformation. While the expanding network of HTA programs is poised to significantly impact Brazilian healthcare, additional institutional advancements could expedite progress. The study recommends establishing a national HTA agency by the Federal Ministry of Health in Brazil to consolidate and enhance ongoing developments.

Diverging from other works presented herein in this related work section, Querme and Lima [14] have championed the automation of coffee production traceability using QR-Codes to optimize processes, enhance quality, fortify safety, and advance sustainability within the supply chain under the Industry 4.0 paradigm. Through meticulous employment of BPMN modeling, the study thoroughly delineates the various stages of coffee production, leveraging the potential of QR-Codes for efficient data collection and registration during key activities such as harvesting, washing, drying, processing, storage, and farm certification validation. QR-Codes play a pivotal role in streamlining operations, mitigating errors, and enhancing traceability, with active engagement from stakeholders spanning harvesters to quality personnel, inspectors, and clerks. The research systematically scrutinizes the intricate journey of coffee from rural producers to warehouses, thereby optimizing stock and refining delivery management. The noteworthy outcomes encompass a substantial reduction in the workforce, diminished activities leading to a consequential reduction in time, and a discernible enhancement in the precision of completing the entire process.

The reviewed articles highlight the significance of utilizing BPMN for process modeling, emphasizing the need to identify problems, gaps, and limitations within the queue. Moreover, it is crucial to address these issues by optimizing processes through IT systems. In the healthcare sector, it is imperative to acknowledge that technological innovations play a pivotal role in enhancing access to medical care and alleviating waiting times [29].

3. Study Case

In this section, we will introduce the authors who played a pivotal role in the BPMN process implementation in Ibiá, MG, Brazil. The following subsection highlights the main gateways involved in this healthcare scenario in Ibiá. This scenario is presented before proposing a new workflow that models the new process in an automated way.

3.1. Actors

In our BPMN model actors, these individuals, through their expertise and collaborative efforts, have contributed significantly to the successful development and deployment of the BPMN model in the local healthcare system. Their in-depth understanding of BPMN principles and commitment to enhancing healthcare processes in Ibiá have been instrumental in achieving the goals of transparency, efficiency, and improved patient care.

General Practitioner/Nursing: the medical employees in our real scenario, modeled through BPMN, present four essential activities:

1) Receive Patient (Screening): The nursing or general practitioner performs an initial assessment, determining if immediate medical attention is needed or if a referral to another medical area is appropriate.
2) Examine the Patient (Medical Care/Nursing): Once the decision is made to provide medical attention, the doctor diagnoses the patient's illness and prescribes a suitable treatment plan.
3) Prescribe Referral to Specialty: The general practitioner generates a comprehensive medical report certifying the patient's health status and detailing the administered treatment. If necessary, the general practitioner prescribes a referral to a specialist.
4) Request Exams: General practitioner requests necessary exams for the patient.

Health Secretary Coordinator: the health coordinator assumes responsibility for managing medical care and basic health requests. Additionally, they oversee and control the specialty queues within the Unified Health System, in Portuguese Sistema Único de Saúde (SUS), particularly those with a limited number of authorized services. This encompasses monitoring and controlling these services.

1) Sign to Authorize Exams: The coordinator authorizes patients to undergo necessary medical exams.
2) Sign to Authorize Specialized Medical Care: Coordinates the patient's referral to another medical specialty.
3) Manages the Medical Specialty Referral Queue: Oversees and manages the queue of patients within the municipality of Ibia, Minas Gerais, Brazil.

Health Secretariat: the health secretariat oversees and controls all municipal health management processes. Their role involves making decisions on whether to authorize specific procedures, adhering to guidelines from state, regional, and federal health bodies. This includes monitoring health procedures at the municipal level in alignment with established guidelines.

1) Register Patient: Records patient data within the health unit.
2) Show Patient Position in Queue: Provides information on the patient's position in the queue.
3) Check General Practitioner Availability: Checks if nursing or a general practitioner is available to screen the patient.
4) Notify Patient of Unavailability: Informs the patient if there is no general practitioner or nursing available at the health unit.
5) Place Patient on Waiting List for Specialist: Adds the patient to the queue, awaiting consultation with a specialist.
6) Notify Patient: Notifies the patient about the availability of a specialist practitioner.

Patient: From a health perspective, the patient is a citizen with rights and responsibilities. They have the right to request medical care in accordance with Article 196, which outlines health as a universal right guaranteed by the State. The patient seeks access to actions and services aimed at promoting, protecting, and recovering health, as outlined in the Brazilian Constitutional[3] source.

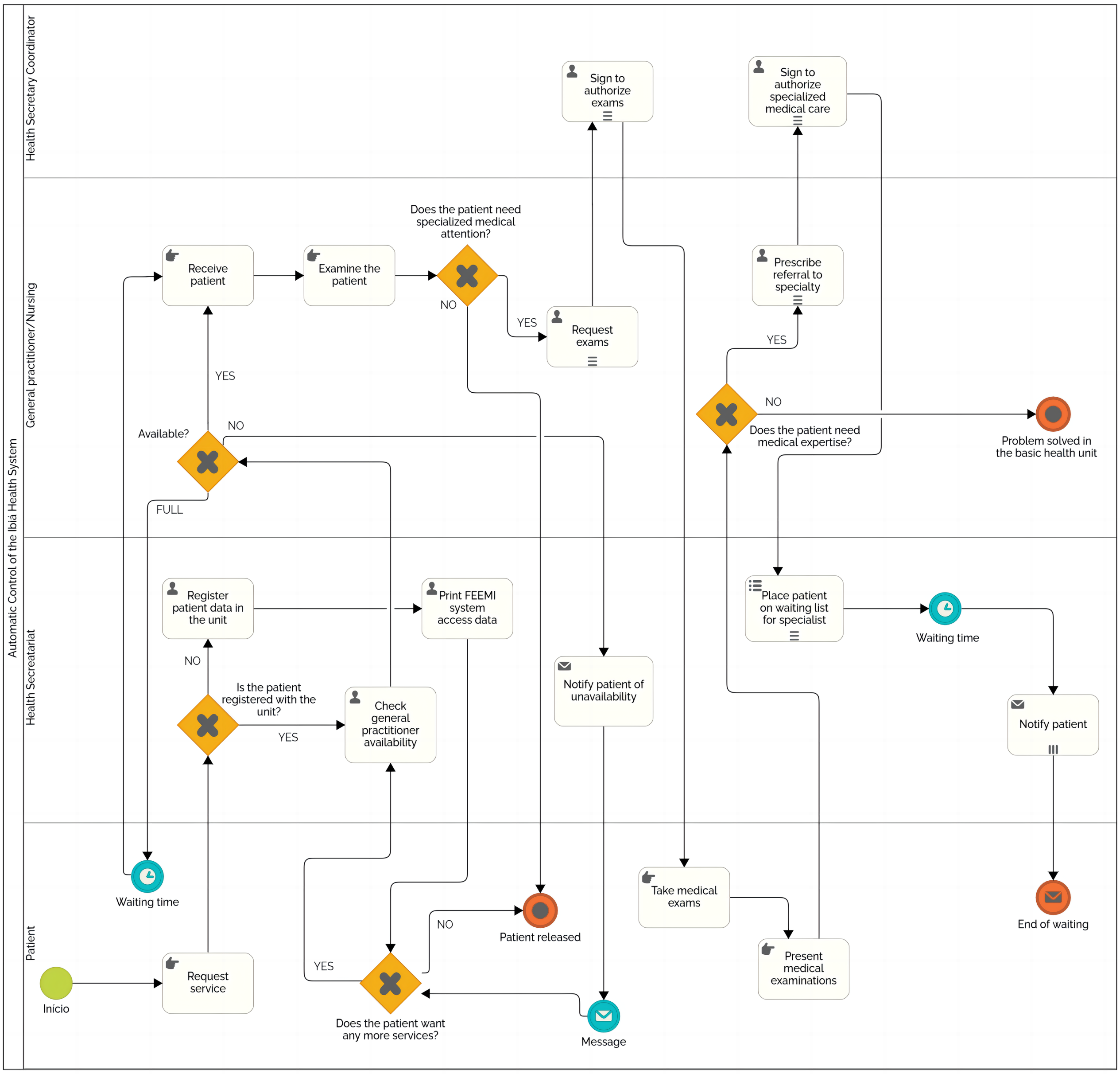
1) Request Service: The patient arrives at the health unit and requests medical service.
2) Take Medical Exam: Undergoes medical exams if deemed necessary.
3) Present Medical Examinations: Presents the results of medical examinations if required.

Therefore, the following diagrams in BPMN demonstrate a little of the old approach manually, and the new approach via the web system, as shown in Figures 1 and 2.

4. Proposal

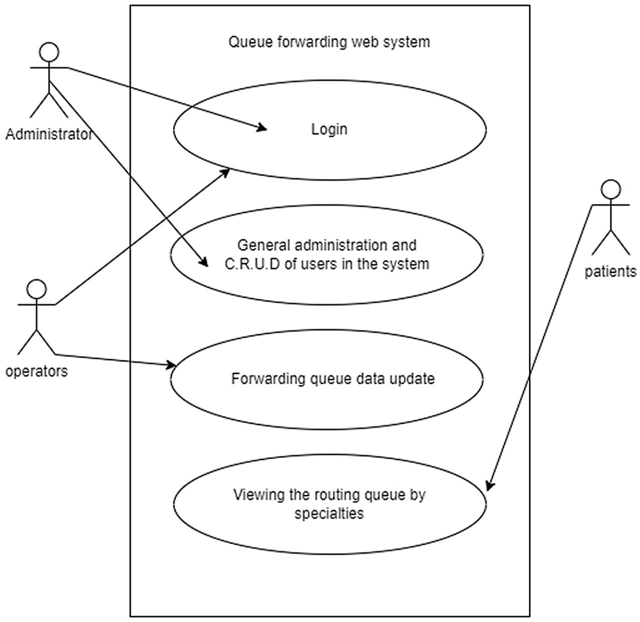
In this section, we will delve into an elucidation of the various stakeholders engaged with the system, encompassing an exploration of system requirements, which includes considerations for the audience, the technological aspects of system design, and specific features tailored for patients. Additionally, we will elucidate the software architecture that underlies the system's functionality. Furthermore, we will provide a comprehensive overview of the proposed BPMN subsequent to the automation facilitated by our IT systems, offering insights into the optimized workflow that aims to streamline and enhance operational efficiency.

Figure 1
BPMN representation of automatic exam requests through the routing queue FEEMI system automation, comprising 5 manual tasks, 10 automatic IT system tasks, and 4 authors



[3]Brazilian Federal Constitution, available in: https://www.planalto.gov.br/ccivil_03/constituicao/constituicao.htm

Figure 2
General user case depicting 4 functionalities and involving 3 actors



4.1. Workflow proposed

Understanding the intricacies of public health administration and business processes is paramount for proposing meaningful improvements. In this context, our approach involves a comprehensive examination of the current manual process employed in managing queues within the public health domain. By meticulously dissecting the existing challenges and bottlenecks, we aim to lay the groundwork for a more efficient and responsive system.

Following the thorough analysis of the manual process, our next step involves the manual modeling of the process using BPMN, see Figure 3. This visual representation allows us to articulate the complexities of the current system, providing a clear map of its workflow and potential areas for enhancement.

Subsequently, armed with insights from the manual BPMN modeling and a deep understanding of the challenges inherent in the existing process, we will embark on designing a new, optimized process. This redesigned model will prioritize organized activities, integrating information systems strategically to automate specific aspects of the process. The goal is to create a more attractive, swift, and secure system that addresses the needs of the population dependent on public health services.

Crucially, our system places a strong emphasis on user-friendliness, guided by Nielsen's Heuristics. By adhering to these usability principles, we ensure that the redesigned system aligns with the intuitive expectations of its users. Besides that, it is important to consider that the context of this paper revolves around a healthcare system or application designed to manage patient queues for medical specialty services in the municipality of Ibiá, Minas Gerais. The system serves a diverse set of users with distinct roles and access requirements. It also operates within the framework of government healthcare IT systems at municipal level.

The primary focus is on providing efficient access to medical services and patient queue information. The document discusses the target audience and system requirements for this healthcare application. This user-centric focus aims to enhance the overall experience, fostering accessibility and ease of use for the population seeking public health services. Through this holistic approach, we aspire to contribute to a more efficient, responsive, and user-friendly public health management system, meeting the diverse needs of the community.

4.2. Audience

The application's end-users are patients, representing the general population. Their primary use of the system is to monitor their positions in the service queues. Patient profiles are diverse, and the application aims to be as user-friendly as possible, considering the potential challenges faced by individuals from various backgrounds. Patients use the system to check their positions in the queue for medical services.

The primary audience comprises administrators who have full access to the system. These individuals are responsible for creating new user profiles and managing the application. They are typically civil servants working at municipal, state, or federal levels, and their responsibilities often extend to other government healthcare systems. Operators, who are also part of the administration team, are responsible for feeding the system with data related to patients in service queues. They have limited access, primarily focusing on data input and maintenance. Their role involves patient registrations, updates, and removals, as well as managing the list of services by specialty.

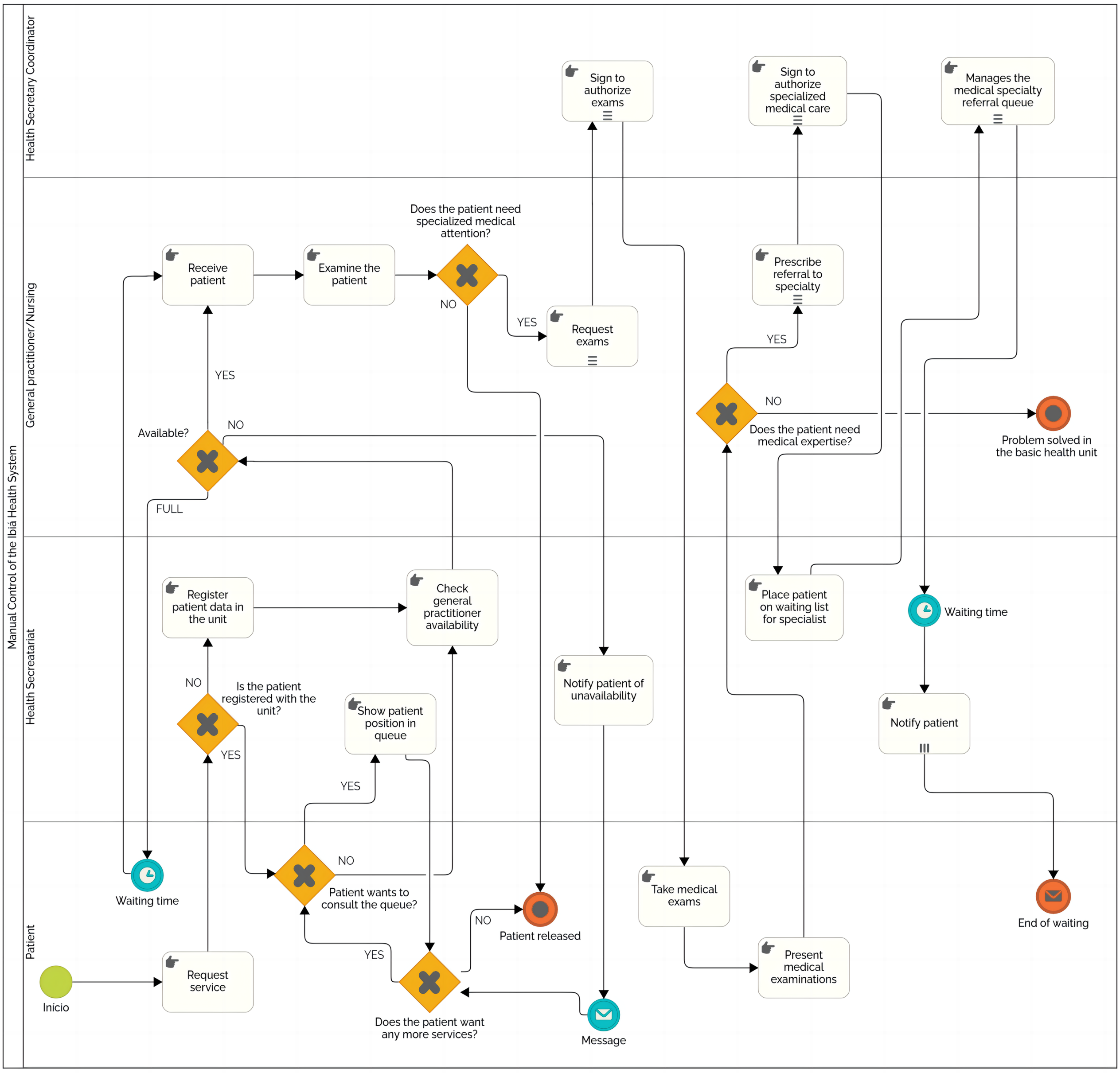
The document's context and requirements are also relevant for the technical team responsible for developing and maintaining the system. It outlines the technical specifications and technologies used for both front-end and back-end development, including Structured Query Language (MySQL) for database management, Laravel Framework Hypertext Preprocessor (PHP), JavaScript, HyperText Markup Language (HTML5), Cascading Style Sheets (CSS3), and Bootstrap for creating the web application, and other libraries like Chart.js for visualizing data. Besides that, it is important to consider professionals responsible for ensuring that the application is responsive across different device screens should also take note of the technologies mentioned, as this is critical for ensuring usability for the diverse audience, including patients accessing the system from various devices.

4.3. Requirements

The requirements for the healthcare application in Ibiá are designed to meet the diverse needs of operators, patients, and other stakeholders. These requirements are aimed at creating a user-friendly and responsive system, ensuring smooth interaction and efficient management of the medical specialty queue.

The presented general user case diagram, as depicted in Figure 2, outlines four crucial functionalities and involves three primary actors. The first use case, "Login", is vital for both administrators and operators, emphasizing the importance of secure access to the system. The second use case involves the "General Administration of CRUD" operations (Create, Read, Update, and Delete), primarily managed by administrators. This functionality underscores the system's capability for efficient data management and manipulation. The third use case, "Queue Patient Management," is centered around operators, allowing them to oversee and manage the patient queue effectively. Lastly, the fourth use case, "Viewing Queue for Specialists," caters to patients, providing them with the ability to view their positions in specialty care queues. The FEEMI system demonstrates its versatility by catering to the varied needs of

Figure 3
BPMN representation of manual exam requests and manual queue management without automation, featuring 16 manual tasks and 4 authors



administrators, operators, and patients in the health referral process. Essential features and technologies for successful system implementation will be presented in the following subsections.

4.3.1. Operator features

The healthcare management system is carefully structured to accommodate the roles and responsibilities of administrators and operators. Administrators hold the highest level of access, with the authority to oversee user management, generate reports, and manage patient records and medical specialties. Operators, divided into level 1 and level 2, play pivotal roles in patient queue maintenance, facilitating efficient patient management, and contributing to the overall effectiveness of the healthcare system. This well-defined user structure is crucial for streamlining healthcare operations and ensuring the seamless delivery of services in Ibiá, MG, Brazil.

Level 1 operators have a higher level of access compared to their level 2 counterparts. Their responsibilities encompass: (i) patient record administration, including registration, updates, and removal from the waiting list. (ii) Associating patients with specific waiting specialties. (iii) Viewing reports related to the services provided. (iv) Level 1 operators often perform these tasks within healthcare units, facilitating patient management and service coordination.

Level 2 operators primarily handle basic support functions with limited access compared to level 1 operators. Their functions are as follows: (i) inclusion of patients in the queue. Updating patient queue information, whether or not the patient has been attended to. (ii) Viewing reports related to the services. (iii) Level 2 operators typically provide essential typing and support functions, ensuring that patient data remain up to date and accurate.

Administrators have the highest level of privileges within the system. They are responsible for approving new users who self-register on the system. Besides that, it is important that they assign users to specific access profiles (e.g., operator level 1 or operator level 2). Creating new user profiles manually is another responsibility and also managing users by adding, updating, removing, changing access profiles, or deactivating profiles. Besides that, they are responsible for viewing and managing system reports. Exporting lists in various file formats like EXCEL, CSV, managing patient data, including additions, updates, and removals, managing data related to medical specialties. Administrators serve as the gatekeepers of the system, ensuring its integrity and functionality. Here is a summary of the main activities of the technical actors involved in the system.

1) Operator Registration: The system must allow administrators to register new operators with their respective roles and access levels.
2) Updating Operators: Administrators should have the capability to update operator profiles as necessary, reflecting changes in their roles or responsibilities.
3) Operator Removal: The system should provide a feature for the removal of operators if they are no longer involved in the system.
4) Patient Management: Operators need the ability to register new patients, update patient information, and remove patients from the queue as needed.
5) Specialty Service Lists: Operators must be able to manage and update lists of services offered by specialty, ensuring that the information is accurate and up to date.

4.3.2. Patient features

The patient profile accommodates any individual, including citizens and interested parties, who wish to check their position in the specialty care queue served by the SUS in Ibiá, Minas Gerais. Users in this profile can either self-register or be registered by an administrator and subsequently access a list that displays their queue position, chosen specialty, and the order of service, facilitating easy monitoring of their progress. Patients can self-register or be manually registered and monitor their position in the specialty care queue, promoting transparency and engagement in the healthcare process.

1) Specialty-Based Filtering: Patients accessing the system should be able to view the list of medical services based on specialty filters. This feature enables patients to easily locate the services they require.
2) Export Capability: Patients should have the option to export the information they access in a file format, allowing them to keep a record of their position in the queue and planned medical services.
3) Simplified Queue Search: The system should provide a simplified search feature for patients to locate their positions in the service queue quickly.

This diverse set of user profiles ensures that the system effectively serves the needs of all stakeholders in Ibiá, MG, Brazil.

4.3.3. System design and technology

The enumerated list outlines key features and technologies crucial for the development of an effective and user-centric system designed to optimize the management of medical specialty queues in Ibiá, MG, Brazil. These essential components collectively contribute to creating a seamless and efficient experience for both operators and patients, aligning with the overarching goal of enhancing healthcare accessibility and service delivery. The detailed specifications include:

1) User-Friendly Interface: The system needs to be intuitive and simple for patients with varying levels of digital literacy and backgrounds. This user-friendliness is essential to ensure effective use of the system.
2) Relational Database: The back-end should utilize a relational database, such as MySQL, to efficiently manage patient data, operator information, and service queues.
3) Laravel Framework PHP: The system's back-end should be built on the Laravel Framework in PHP, offering robust, scalable, and maintainable code for efficient operation.
4) JavaScript: JavaScript is essential for creating dynamic and interactive features within the application, enhancing the user experience.
5) Front-End Technologies: The front-end of the application should be developed using HTML5, CSS3, and Bootstrap to provide a visually appealing and responsive design.
6) Data Visualization: Utilize Chart.js to create interactive and informative graphics, which can help in visualizing queue data and service availability.
7) Input Masking: iMask should be used for input fields, enhancing data entry accuracy and making it easier for operators and patients to provide information.
8) Iconography: Incorporate Font Awesome icons to enhance the visual appeal and usability of the system.
9) Responsive Design: The system must be responsive, ensuring that it adapts seamlessly to various device screens. This is crucial to enable access from different types of devices, including smartphones, tablets, and desktop computers.

These requirements emphasize the importance of a user-friendly and responsive healthcare application in Ibiá, Minas Gerais, Brazil. The features and technologies mentioned are essential for both operators and patients to efficiently manage and access the medical specialty queue, contributing to improved healthcare services and accessibility for the community.

4.4. Software architecture

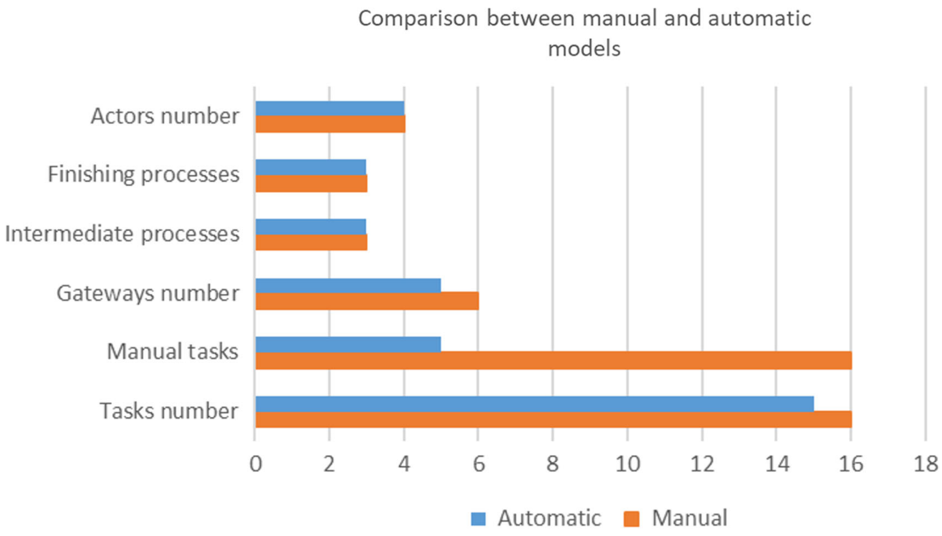
The software architecture adopted for this application is the model-view-controller (MVC) pattern. In this architectural framework, each component serves a distinct role in managing the application's functionality. The view layer utilizes attributes from Laravel PHP in conjunction with HTML5 to present the user interface, while CSS3 is used for styling. The model layer is responsible for implementing the business rules, specifically handling service queues and other data, as well as interacting with the MySQL database for data access and manipulation. The controller layer acts as the intermediary that connects the view and the model. The choice of the MVC architecture is driven by the application's simplified nature. It takes into consideration specific database-related aspects, such as the need for data standardization and encryption. This approach ensures that data remain consistent and structurally persistent, contributing to the application's overall robustness and reliability.

5. Results

In this section, we will present the manual and automated patient queue management processes, followed by a showcase of the FEEMI system, highlighting usability, unit test results, and qualitative screen analysis. The official application address[4] is the primary online gateway for system access. This web address, found in the footnote, serves as the designated entry point for administrators, operators, and patients, providing a secure platform for managing medical referrals,

[4]Access the application at https://encaminhamento.ibia.mg.gov.br

Figure 4
Bar chart comparing optimization between manual process and automatic process



service queues, and healthcare activities. The FEEMI is accessible through the application, enabling users to utilize its features and contribute to improving healthcare services in Ibiá, MG, Brazil.

5.1. Business process analysis

This study compares two approaches to process modeling in the context of a Health Referral Queue System, evaluating the manual and automatic creation of BPMN diagrams, as is possible to see in Figure 4. The manual BPMN method involves 16 tasks, all of which are manual, with 6 gateways, 3 intermediate processes, 3 finishing processes, and 4 actors. In contrast, the automatic BPMN method streamlines the process with 15 tasks, reducing manual tasks to 5, accompanied by 5 gateways, and maintaining 3 intermediate and 3 finishing processes, along with the same number of actors, totaling 4. This quantitative analysis sheds light on the efficiency and differences between manual and automatic BPMN modeling in the context of a Health Referral Queue System.

On the other hand, in a qualitative analysis, the BPMN Automatic approach, using system FEEMI proposed herein, offers significant benefits, especially for patients in the Health Referral Queue System. The reduction in the number of manual tasks from 16 to 5 in the automatic BPMN method suggests increased efficiency and streamlined processes. This translates to quicker responses and services for patients, minimizing delays and potential errors associated with manual interventions. The decrease in the number of gateways and maintenance of intermediate and finishing processes in the automatic approach further implies a more straightforward and coherent system. Patients are likely to experience a smoother journey through the healthcare process, with automation contributing to a more efficient and patient-friendly experience. The consistent number of actors in both approaches ensures that the essential roles in patient care are maintained, providing continuity in the quality of healthcare services. Thinking in patient and public management, the BPMN Automatic method appears to be a favorable choice for improving the patient experience within the Health Referral Queue System.

5.2. Software FEEMI analysis

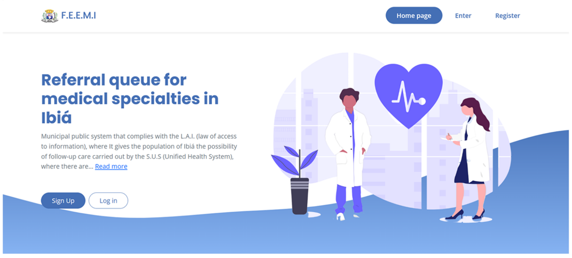
In this section, we provide an overview of the final application screens, discuss the outcomes of software testing, and evaluate the usability of the system using Nielsen's Heuristics. The final application screens include interfaces designed for various user roles, such as level 1 operators in basic health units, level 2 operators like receptionists, patients monitoring specialty care queues served by the SUS, and a self-registration screen for user registration within the system. The software testing phase involves a series of unit tests, each simulating different scenarios to ensure the proper functioning of critical functionalities. Furthermore, we conduct a usability analysis using Nielsen's Heuristics, assessing aspects such as system visibility, user control, error prevention, and overall efficiency of use. This comprehensive approach aims to provide insights into the functionality, robustness, and user-friendliness of the developed application.

5.2.1. Final application screens

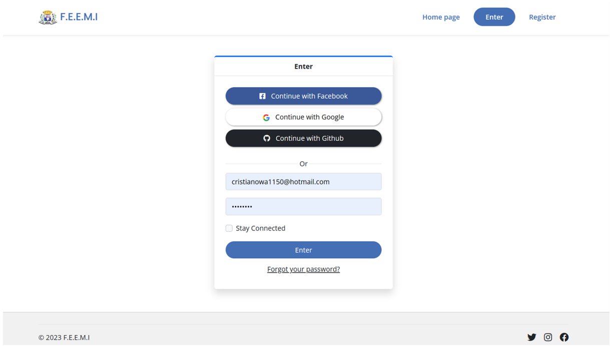
The application's interface is meticulously presented, detailing descriptions within specific fields and depicting the access flow commencing at the login screen. This section represents key aspects of the application's user interface, catering to various user profiles and their specific roles within the system. Users are then directed to their respective screens from beginning in Figure 5(a) and then including the administrative screen, followed by level 1 and 2 operator profiles, and culminating with the patient view, as is shown in Figure 5. It is worth noting that each user has the potential to assume various roles, ranging from administrator to operator profiles, or simply the role of a patient. The system is equipped with a superuser account that cannot be removed, while administrators have the flexibility to be relocated to other profiles. The login screen, which serves as the gateway to the system, determines the user's access profile, directing them to their specific routes while maintaining essential security measures, as is shown in Figure 5(b), which serves as the initial point of access for users. It is here that individuals with varying access profiles, including administrators, operators, and patients, provide their credentials to enter the system.

Figure 5
Screenshots of FEEMI system user interfaces. Sub-figures depict various screens, including the login interface, initial user access point, administrative interface, and statistics screen, showcasing the system's diverse functionalities

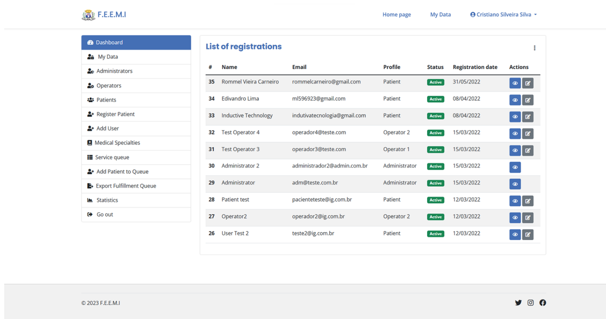
(a) System's login screen, which serves as the initial point of access for users



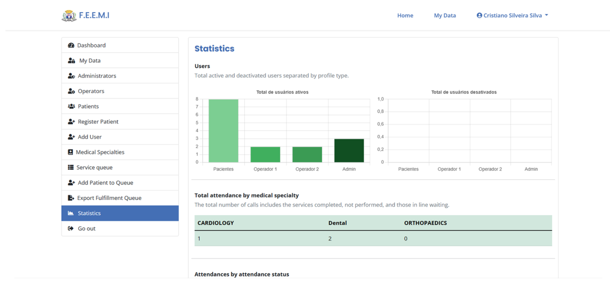
(b) System's initial interface point of access for users



(c) Administrative screen, accessible to those with administrative privileges



(d) Administrative statistics screen, providing administrators with valuable insights into the system's performance



It is essential to clarify that all information presented in the test environment is entirely fictional, featuring no real-world restrictions, and incorporates robust encryption methods to secure sensitive data, including passwords and the envfile. The flow sequence presented here encompasses the sequence of login, the administrative screen, see Figure 5(c), this interface empowers administrators to manage users, create and assign access profiles, and oversee the system's critical functions, such as patient and medical specialty data. The administrative statistics screen, see Figure 5(d), provides administrators with valuable insights into the system's performance. It allows them to monitor essential statistics, including the number of patients treated, service waiting times, active and deactivated users, as well as statistical data categorized by various medical specialties and services.

Figure 6(a) illustrates the interface for level 1 operators, often situated in basic health units and some specialists' offices. Level 1 operators possess heightened privileges that enable them to manage service queues efficiently. They can perform tasks such as patient registration, updates, and removal from queues, along with associating patients with specific specialties. Figure 6(b) depicts the interface designed for level 2 operators, typically receptionists at health units. Level 2 operators have a simplified, yet essential, role. Their responsibilities revolve around data input and updates within the system. Ultimately, the system concludes with the user self-registration screen, offering a comprehensive view of the application's user experience.

The management of user data across various access profiles is a central aspect of the system's functionality. Administrative accounts play a pivotal role in overseeing user data and statistical information. These administrators typically consist of individuals from the information technology department of the city of Ibiá and health unit coordinators. They possess application management profiles, allowing them to populate the system with users, assign access profiles, and make profile adjustments when required. Additionally, administrators manage patient and medical specialty data, which forms the basis for the service queues. In contrast, level 1 operators are primarily situated in basic health units and, in some instances, include specialists responsible for administering queues within their respective units. Level 2 operators, who typically act as receptionists at health units, have a more simplified and limited profile. Their responsibilities encompass data input and updates.

Figure 7(a) displays the interface tailored to patients, who seek to monitor their positions in specialty care queues served by the SUS. Patients can register themselves manually or through available services, view their queue positions, select their desired medical specialties, and track their progress efficiently. Patients accessing the system have the option to register manually or employ available services, such as social media accounts or Google, for streamlined registration. Once registered, patients are guided to complete their personal data, which can be deferred but is essential for requesting assistance and inclusion in the queue. Level 2 access, attributed to level 2 operators, offers guidance on updating patient data and managing the service queue.

For level access, operators have slightly reduced privileges compared to administrators, permitting them to register patients under their care units, record medical specialties, manage queues, and add patients to the queues. In Figure 7(b), we see the self-registration screen, accessible to users interested in registering themselves within the system. This interface enables users to create their profiles and access the system's functionalities, contributing to transparency and engagement in the healthcare process. Administrators enjoy the broadest privileges, encompassing all available actions, including monitoring statistical data on patient treatment, service waiting times, user activity, and statistics related to various medical specialties and services.

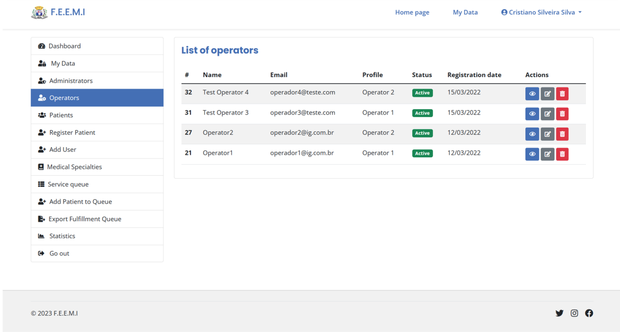
5.2.2. Software testing

The testing phase of the system's development involved both unit testing and browser testing to ensure the reliability and functionality of the application. Unit tests were conducted using the PHPUNIT framework, enabling comprehensive testing of

Figure 6

Screenshots of FEEMI system user interfaces. Sub-figures showcase interfaces tailored for different user roles, including level 1 operators, level 2 operators

(a) Interface for level 1 operators, often situated in basic health units and some specialists' offices



(b) Interface designed for level 2 operators, typically receptionists at health units

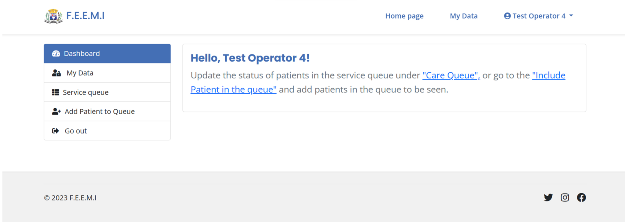
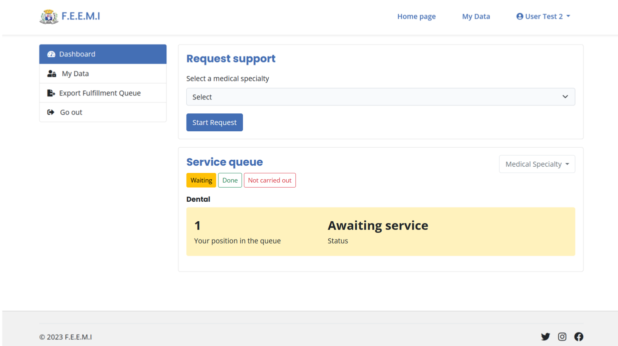


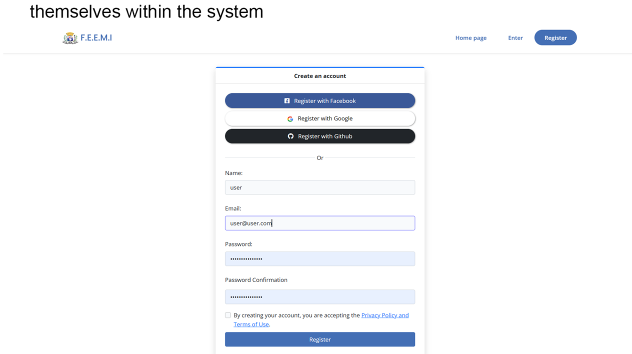
Figure 7

Screenshots of FEEMI system user interfaces, sub-figures showcase interfaces tailored for patients monitoring specialty care queues served by the SUS, and a self-registration screen for user registration within the system

(a)Interface tailored to patients, who seek to monitor their positions in specialty care queues served by the SUS



(b)Self-registration screen, accessible to users interested in registering themselves within the system



various system functionalities. Details of all test commands, as well as their descriptions, are meticulously documented in the README.md file within the source code. This documentation aids in understanding and replicating the testing procedures.

In addition to unit tests, the system underwent browser tests to validate user interactions and automated simulations. These browser tests were instrumental in evaluating user registration and login processes within the system, leveraging the Laravel Dusk framework for automation. The results of these tests, which included successful unit tests and simulations of potential errors, are outlined in Figure 8(a), which provides a visual representation of successful unit tests, confirming that all tested functionalities passed without errors.

This affirms the system's capability to execute critical processes seamlessly. Additionally, the simulation of errors during user registration and login processes, illustrated in Figures 8(b) and 8(c), demonstrates the system's resilience in detecting and effectively handling potential issues. The absence of errors in these simulations underscores the system's robust error prevention mechanisms. Figure 8(d) further reinforces the reliability of the login process, as the successful completion of this test affirms that users can access the system as expected. These unit test results instill confidence in the FEEMI system's functionality, emphasizing its ability to perform reliably across various scenarios.

5.2.3. Nielsen heuristics analysis

In this section, we present 10 Nielsen's Heuristics, as shown in Table 1. These heuristics serve as valuable guidelines for improving the usability and user experience of software applications and websites. Besides that, the evaluation of the FEEMI system's usability, based on Nielsen's heuristics, provides valuable insights into its user interface design and overall user experience. The analysis reveals a strong adherence to several critical usability principles.

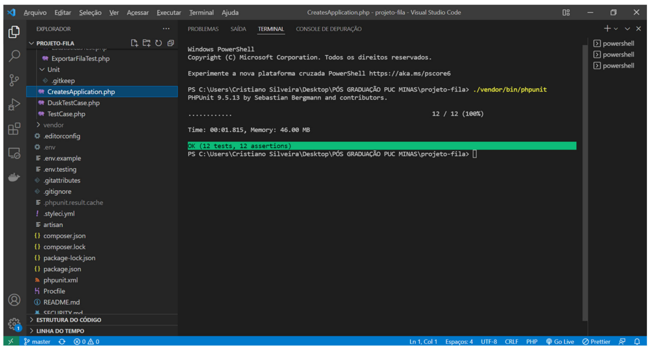
For instance, the system scores an 8 in the "Visibility of System Status" (Heuristic 1), indicating that it effectively keeps users informed about ongoing system activities. This feature is crucial for ensuring users are aware of the system's state, actions, and any potential errors or delays. The system demonstrates excellence in "Match Between System and Real World" (Heuristic 2) and "Consistency and Standards" (Heuristic 4), earning a perfect score of 10 for both. These high scores signify that the FEEMI system aligns well with users' mental models and maintains consistency in design elements throughout the interface, following established standards. On the other hand, the FEEMI system excels in providing user control and freedom, scoring a 9 in this aspect (Heuristic 3). The system allows users to navigate effortlessly, recover from errors, and provide features like the "undo" option, enhancing user autonomy.

Moreover, the system excels in "Error Prevention" (Heuristic 5) and "Recognition Rather Than Recall" (Heuristic 6), both essential for minimizing user mistakes and reducing cognitive load. The evaluation

Figure 8

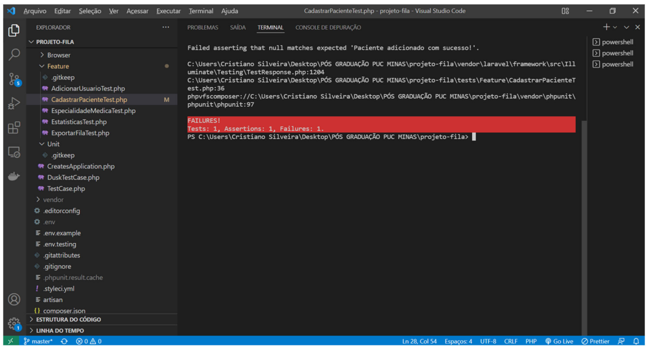
Unit test results for FEEMI system functionalities. Sub-figures illustrate successful unit tests for user registration, error simulations, and login processes, confirming the system's robust functionality

(a)



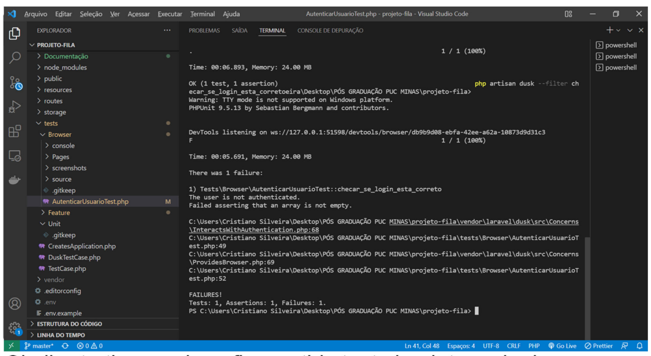
This figure indicates that all unit tests have passed successfully, affirming the proper functioning of the tested functionalities

(b)



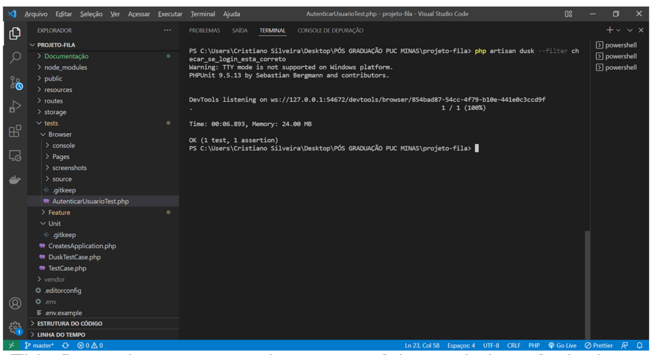
test simulates an error during user registration, highlighting the system's ability to detect and handle such errors effectively

(c)



Similar to the previous figure, this test simulates a login error, showcasing the system's ability to identify and manage login- test related issues

(d)



This figure demonstrates the successful completion of a login, confirming that the login process functions as expected

Table 1
Evaluation of FEEMI system usability based on Nielsen's Heuristics

ID	Heuristic	Description	Grade
01	Visibility of system status	Keep users informed about what is happening within the system. Provide clear feedback on actions, errors, and loading times	8
02	Match between system and real world	Use terminology and concepts familiar to users. Make sure the system mirrors the user's natural way of thinking	10
03	User control and freedom	Allow users to navigate and recover from errors easily. Provide an "undo" feature and clear exit options	9
04	Consistency and standards	Maintain consistency in design elements, such as icons, buttons, and navigation throughout the system. Follow established standards and conventions	10
05	Error prevention	Strive to prevent errors rather than merely offering error messages. Design intuitive interfaces that minimize the likelihood of user mistakes	10
06	Recognition rather than recall	Minimize users' memory load. Present information and options in a visible and easily retrievable manner. Avoid making users remember things from one part of the interface to another	10
07	Flexibility and efficiency of use	Cater to both novice and expert users. Provide shortcuts, accelerators, and efficient ways for experienced users to accomplish tasks	10
08	Aesthetic and minimalist design	Keep the interface uncluttered, emphasizing only essential information. Reduce distractions and prioritize content	10
09	Help users recognize, diagnose, and recover from errors	Offer clear, concise error messages. Guide users on how to correct mistakes and continue using the system	9
10	Help and documentation	Provide accessible, context-sensitive help and documentation that is easy to search and use as a reference when users need assistance	0

suggests that the FEEMI system is designed to prevent errors proactively and presents information in a visible and easily retrievable manner.

Moreover, the system demonstrates outstanding flexibility and efficiency of use (Heuristic 7), scoring 10. It caters to both novice and expert users, offering shortcuts and accelerators for efficient task accomplishment. The aesthetic and minimalist design (Heuristic 8) of the interface is another notable feature, scoring a perfect 10. This ensures that the interface remains uncluttered, prioritizing essential information and minimizing distractions. In terms of helping users recognize, diagnose, and recover from errors (Heuristic 9), the system scores a commendable 9, indicating the presence of clear and concise error messages along with guidance for users to rectify mistakes and seamlessly continue their interactions with the system.

Despite the overall positive evaluation, there are areas for improvement. Notably, "Help and Documentation" (Heuristic 10) received a score of 0, indicating a lack of accessible and context-sensitive help. This suggests an opportunity to enhance the system's support features to aid users when needed. Finally, we can affirm that the FEEMI system exhibits commendable usability, incorporating robust design principles. Addressing the identified areas for improvement, especially in providing helpful documentation, could further enhance the system's overall usability and user satisfaction.

6. Discussion

Besides that, examining the queue software's development in Ibiá, it becomes evident that this solution incorporates principles elucidated in related studies. The software's implementation focuses on refining specialist appointment scheduling, thereby enhancing patient management in primary healthcare within a regional context. These initiatives align with the broader trend of leveraging technology to elevate healthcare standards, increase productivity, improve service efficiency, and subsequently reduce waiting queues. The overarching goal is to enhance the quality of healthcare services in Ibiá, Minas Gerais, and optimize resources within the healthcare sector—an essential objective achieved through the development of the software in Ibiá.

While the cited authors and the Specialty Medical Referral Queue System in Ibiá, MG, address issues related to queue management and healthcare service organization, it is important to note that there are differences between the SISAC software proposed by Bernardes Senna et al. [25] and the system created for the city of Ibiá, MG. The main similarities with our FEEMI system and Bernardes Senna et al. [25] are Goal to Improve Queue Management: Both SISAC software and the Specialty Medical Referral Queue System in Ibiá share the goal of enhancing the management of patient queues in need of specialized medical care. Besides that, Bernardes Senna et al.'s [25] work emphasis on transparency and prioritization: both systems emphasize transparency in queue management and the importance of prioritization based on clinical and chronological criteria. This approach aims to ensure that patients in greater need to receive priority care.

On the other hand, the most different system is SISAC software [25] developed by the cited authors. It is a broader and more general tool for managing surgical queues that can be applied in various healthcare institutions. In contrast, the FEEMI is specifically targeted at municipalities. Additionally, the SISAC software mentions integration with hospital databases and information systems, facilitating automatic data entry. In the case of the Ibiá system, there may be a need to address issues related to integration with medical records and other healthcare systems, such as ESUS AB PEC, for example. Finally, the authors of SISAC emphasize the importance of system validation by experts before implementation. In the case of the FEEMI system in Ibiá, it was implemented in response to a real need but is still in the phase of improvements and refinements. While both systems share the common goal of improving patient queue management in healthcare, SISAC is a broader and more general solution, whereas the Ibiá, MG system caters to specific needs. Each has its distinct characteristics and specific challenges, but both represent innovative approaches to optimizing access to healthcare services.

In comparison to the evaluation of the Brazilian IIS by de Azevedo Guimarães et al. [27], the FEEMI system showcases robust usability features. While the IIS faced challenges with violated heuristics and usability problems, the FEEMI system, evaluated through Nielsen's Heuristics, demonstrates a high degree of usability. Notably, the FEEMI system excels in areas such as visibility of system status, user control and freedom, flexibility, and efficiency of use, as well as aesthetic and minimalist design. These aspects contribute to a user-friendly interface and positive user experiences, distinguishing the FEEMI system from the evaluated IIS.

The FEEMI system also stands out from the study on HTA in Brazil by Banta and Almeida [28]. While the HTA study focuses on the broader landscape of healthcare technology, the FEEMI system addresses a specific operational challenge within healthcare service delivery. The FEEMI system's targeted approach to health referral queue management exemplifies how innovative IT solutions can optimize specific processes, such as medical specialty referrals, contributing to efficiency gains and improved patient outcomes.

In contrast to the automation of coffee production traceability discussed by Querme and Lima [14], which operates outside the healthcare domain, the FEEMI system addresses critical issues within the healthcare sector. While both studies leverage BPMN modeling, the FEEMI system's focus on health referral processes showcases the adaptability of BPMN in diverse contexts. The FEEMI system contributes to healthcare process optimization, reducing manual tasks, and enhancing overall efficiency in managing medical specialty referrals. The FEEMI system stands out as an innovative solution tailored to the challenges of health referral queue management, providing a comprehensive and user-friendly approach to enhance the efficiency and transparency of healthcare services in Ibiá, MG, Brazil.

7. Conclusions

The development of the system proposed herein, known as "FEEMI – Specialty Medical Referral Queue System in Ibiá," represents a significant enhancement in access to specialized medical services in Ibiá, MG, Brazil. It improves the process of managing and monitoring service queues with greater efficiency and transparency. The application fills a gap in the healthcare system, where patients often struggle to check their position on waiting lists and receive updates about their treatments. With the implementation of this system, both patients and healthcare professionals and administrators will have tools that simplify queue management and provide valuable real-time information. Key individuals in this system, such as administrators, operators, and patients, have different profiles, each with specific functions. Administrators are responsible for managing the system, approving new users, and updating information. Operators play a crucial role in entering and updating patients in treatment queues, while patients have the opportunity to check their position in the medical specialty queue.

The system was designed based on the MVC architecture, facilitating its maintenance and future expansion. In addition, unit and browser tests were conducted to verify the system's stability and performance. The official launch of the web application and its source code repository on GitHub is a significant milestone, making the solution accessible to all interested parties. We hope that this system will help improve the patient experience in Ibiá and optimize medical waiting queue management.

In addition to its technical attributes, the incorporation of the FEEMI system into the public health management framework of Ibia holds considerable implications. The automated system not only yields operational efficiency through the diminution of manual interventions but also elevates the standard of health services. For individuals seeking medical care, the implementation of the FEEMI system signifies a pivotal juncture, instigating improvements in their overall well-being and instilling a heightened sense of assurance in the diverse facets of health management processes. This study serves as an exemplar of the transformative influence wielded by technological solutions on public health systems, underscoring the imperative for sustained innovation to effectively address the evolving challenges encountered within the realm of healthcare.

However, it is important to emphasize that this is just a first step, and there is room for further expansion and improvements. Other measures, such as integration with existing healthcare systems, may be considered in the future. This project demonstrates how technology can be efficiently used to solve real-world problems and improve the quality of public services. We hope that FEEMI becomes a positive reference in the healthcare sector and an example of how innovation can positively impact local communities.

Future efforts in the context of queue management and healthcare systems are likely to focus on improving the user experience and system effectiveness. A promising direction is to include support features, such as FAQs documents and WhatsApp support, so that users can easily access relevant information and receive real-time assistance. Furthermore, to minimize errors that may occur during system usage, it is important to enhance error messages to make them more informative and solution-oriented. Working on integration with healthcare systems, such as electronic health records and clinical databases, provides a more holistic view of cases, enabling more precise and rapid decision-making.

Furthermore, it is crucial to optimize the FEEMI application by enhancing key security system components to comply with the Brazilian personal data regulations, ensuring robust protection for patient data [30, 31]. These improvements represent an opportunity to make queue management systems more efficient and patient-centered, thereby contributing to higher-quality healthcare.

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Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Author Contribution Statement

Cristiano S. Silva: Conceptualization, Software, Validation, Formal analysis, Investigation, Resources. **Rommel V. Carneiro:** Methodology, Supervision. **Danielli A. Lima:** Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration.

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